Fabrication Process and Plasticity of Gold-Gold Thermocompression Bonds

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ABSTRACT

Wafer bonding adds flexibility to the design and fabrication of many solid-state devices. Silicon direct bonding has been enabling in SOI and other silicon-based multi-wafer devices. However, joining of different substrate materials is desirable in some applications. Thermal constraints may demand the utilization of a low temperature bonding process. In addition, wafer-level sealing near the end of a fabrication sequence can greatly facilitate device packaging. All of these attributes could be met by thermocompression bonding.

Gold is often the preferred intermediary layer used in thermocompression bonding. It is the bonding material under study in the present work. Wafer-level thermocompression bonding has been demonstrated with four-inch wafers under a moderate pressure of 0.5 MPa and temperature of 300°C (1). Following thermal oxidation and patterning of the resist mask, Ti and Au are e-beam deposited onto all wafers. The resist mask is then lifted-off, resulting in groups of 60 mm by 50 µm lines. To ensure complete removal of organics, wafers are UV ozone cleaned immediately prior to alignment and bonding. Bonding is done under nitrogen ambient. A vertical separation is maintained through the duration of the temperature ramp and stabilization. Separators are then withdrawn as a bonding pressure of 0.5 MPa is applied across the wafer for 10 minutes. Finally, the bonded wafer is diced into narrow strips for mechanical testing.

A four-point bend-delamination technique (2) is used to assess bond toughness. Test is performed using a servo-hydraulic load frame operating in displacement control. Load and displacement data are acquired while crack observations are made with a long-working distance telescope. Figure 1 shows the schematic of a specimen under four-point loading.

Ideally, the load-displacement curve should exhibit the behavior depicted in the inset of Figure 2. The specimen loads elastically until the onset of crack propagation, which is characterized by a load plateau. The load can increase as the crack grows beyond the constant moment region. A typical experimental load-displacement curve is shown in Figure 2. Following initial elastic loading, a discontinuity occurred at loads slightly less than 6 N. Unstable crack growth occurred during that period, since steady-state growth is expected when the crack length significantly exceeds the wafer thickness (2). Load plateau behavior was subsequently obtained, corresponding to stable crack growth. Load fluctuations in the plateau region may be due to differences in the crack propagation velocity on either side of the existing crack. It may also be a result of variation in bond toughness. Fractured surfaces of delaminated test specimens were examined. Figure 3 shows SEM micrographs of a line from a delaminated specimen that exhibits a variation in the extent of plasticity of the gold, not only along the length but also across the width of the line. This local variation in bond toughness would affect the crack propagation path. Bond failure has been observed at both gold-gold and titanium-silicon dioxide interfaces, sometimes within several hundreds of microns of one another of the same specimen.

This paper will describe the processing and mechanical testing techniques employed, results obtained and discuss the factors that affect the mechanical integrity of gold thermocompression bonds.

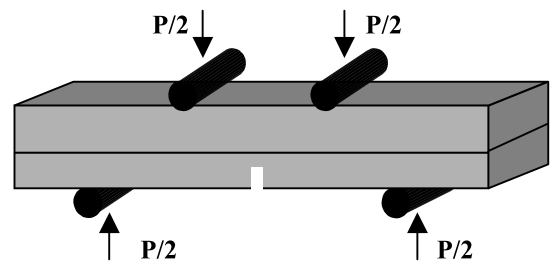

Figure 1 Schematic of a test specimen under the four-point loading.

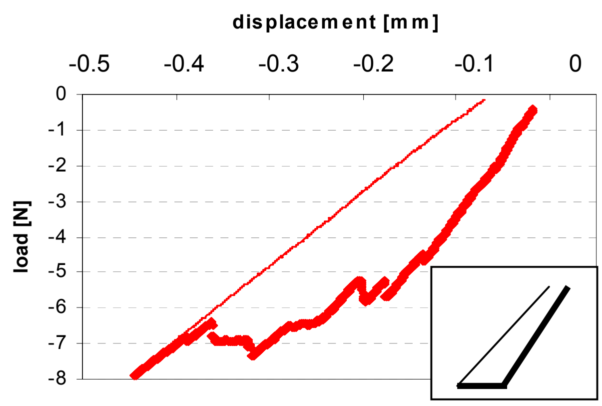

Figure 2 Experimental load-displacement curve. Inset shows the ideal behavior.

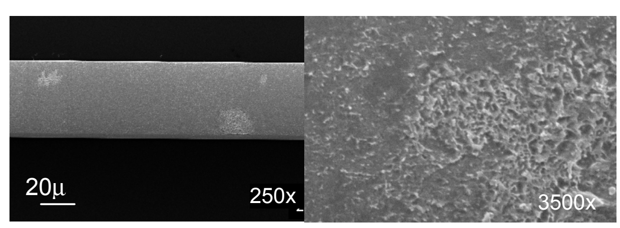

Figure 3 SEM micrographs of a delaminated specimen, showing variation in the amount of plasticity. Right picture magnifies the region outlined on the left.

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